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Variable Pulse Erbium:YAG Laser Skin Resurfacing of Perioral Rhytides and Side-By-Side Comparison With Carbon Dioxide Laser

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Background and Objective: **Laser resurfacing of facial rhytides has become a popular treatment option for many patients with wrinkles, photoaging, and acne scarring. Laser wavelength/pulse duration options and new techniques continue to shorten the healing phase associated with laser skin resurfacing while maintaining clinical efficacy. Variable pulse erbium:YAG (Er:YAG) laser systems are now available that offer the surgeon the ability to vary the Er:YAG pulse duration from a pulse that is primarily ablative to one that is more thermal. The objective of this study was to evaluate the histologic effects created with a variable pulse Er:YAG laser. To study prospectively the clinical effects on upper lip rhytides with a variable pulse Er:YAG laser when compared side by side with pulsed carbon dioxide (CO_2) laser resurfacing.**
Study Design/Materials and Methods: **Forty-two treatment sites on 21 patients were randomized and evaluated after treatment of the upper lip region with CO_2 laser resurfacing on one side and a variable pulse Er:YAG laser on the other. Patient diaries were maintained to assess erythema, crusting, pain, and pigmentary changes. Blinded objective grading of improvement was performed. Chromometer measurements were obtained to analyze erythema.**
Results: **The variable pulse Er:YAG laser treatment reduced the duration of crusting on average from 7.7 days with CO_2 to 3.4 days. Chromometer measurements noted decreased postoperative erythema. Grading by physicians in a blinded manner showed 63% improvement for the CO_2 treatment site and 48% improvement in the variable pulse Er:YAG site. No cases of permanent hyperpigmentation, hypopigmentation, or scarring occurred.**
Conclusion: **The variable pulse Er:YAG laser resurfacing is a safe and**

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effective resurfacing tool, which combines ablative and thermal modalities. The protocol used in this study approaches but does not equal the results we have traditionally seen with CO_2 laser resurfacing. Lasers Surg. Med. 26:208–214, 2000

Key words: variable pulse erbium laser; Er:YAG laser, CO_2; erbium laser; carbon dioxide laser; laser resurfacing

INTRODUCTION

Laser resurfacing techniques for the removal of photoaged skin and the rejuvenation of facial rhytides continue to advance in the effort to optimize wound healing while still achieving maximal clinical results. To date, progress requires certain trade-offs to achieve the laser surgery patient's desire for both the maximal clinical response but minimal recovery time and minimal risk of complications or pigment loss.

The art of laser resurfacing lies in the balance of tissue ablation, dermal injury, and collagen contraction [1–3]. These changes have been well described with the carbon dioxide and erbium:YAG (Er:YAG) laser skin resurfacing systems. The texture and pigmentation improvement after laser resurfacing is primarily the result of tissue ablation of photodamaged skin. This method allows the epidermis the opportunity to regenerate with new nonphotodamaged skin. The contraction and tightening of skin occurs in the dermis within a zone of non-necrotic thermal injury where there exists a mixture of normal collagen and partially denatured collagen [4]. This zone of non-necrotic thermal injury is thought to provide the latticework for collagen remodeling and fibril contraction.

The evolution of laser skin resurfacing has moved from the original CO_2 system to the short-pulsed Er:YAG lasers in the quest to attain shorter durations of patient recovery times and erythema [5–11]. However, increased procedure time (number of passes) and generally less dramatic clinical results with Er:YAG on all but the mildest of rhytides prompted many to return to the CO_2 laser, but the Er:YAG has remained desirable for treating darker ethnic skin [12–20]. The growing incidence of delayed hypopigmentation has emerged as a major drawback with CO_2 resurfacing.

During this time, several groups independently developed "hybrid" combinations of CO_2 and Er:YAG resurfacing in an attempt to capture the best of both techniques [21–23]. Faster recovery, shorter duration of erythema, and the potential reduction of hypopigmentation and hypertrophic scarring were the desirable traits of the erbium "parent," whereas the thermal effect of the CO_2 on wound remodeling and collagen shrinkage were the most desired traits from the CO_2 parent. The goal of the hybrid technique was to thermally injure the desired amount of dermis with the CO_2, thus, also creating a zone of subnecrotic thermal injury. To minimize residual necrotic tissue above this zone of subnecrotic injury, the Er:YAG was used to "debride" down to but not including the layer of subnecrotic injury. The presence of this zone of subnecrotic injury has been nicely demonstrated by Kirsch et al. by using electron microscopy [4].

MATERIALS AND METHODS

Before treatment of patients, an ex vivo histologic analysis was performed by using the variable pulse Er:YAG.(CO_3®, Cynosure, Chelmsford, MA.) On freshly resected face-lift skin, the full spectrum of available pulse durations (350 μs to 10 ms) were tested and compared with the CO_2 laser system. The specimens were pinned under tension during treatment as previously described by Adrian [12].

Forty-two upper lip treatment sites on 21 female volunteers were randomized to either CO_2 or variable pulse Er:YAG laser resurfacing. The CO_2 laser (UltraPulse® 5000-C, Coherent, Palo Alto, CA) was used with two nonoverlapping passes at 300 mJ, 95 W, pattern density 6, spot diameter 2.25 mm, 7.5 J/cm^2 by using the computer pattern generator (CPG). Wiping was performed between passes. Treatment sites were bordered laterally by the nasolabial crease and medially by the center of the philtrum.

The variable pulse Er:YAG laser (CO_3®, Cynosure, Chelmsford, MA.) was used in a protocol that was designed to emulate the combined CO_2/Er:YAG resurfacing technique [21]. A combination of ablative/thermal/ablative techniques were used to attempt to maximize residual thermal damage while still ablating the epidermis and residual necrosis.

Four passes with a 5-mm hand piece at 1.5 J

output (5.2 J/cm^2) were performed at 500 μs pulse duration. This step was followed by one pass with a 5-mm hand piece at 2.6 J/cm^2 at a 10-ms pulse duration. The final pass used a 5-mm hand piece at 1.5 J output or 5.2 J/cm^2 at a 500-μs pulse duration. No wiping was performed between Er: YAG passes. The shoulder regions of rhytides were not individually sculpted as is often performed in private practice patients to limit study variability. The same investigational team performed all treatments under the same operative conditions. A smoke evacuation unit was used (Plume safe®, Model 1202, Medtek Devices, Inc., Buffalo, NY).

A small subset of Asian patients was treated with the variable pulse Er:YAG protocol on one side and six passes on the other lip with a 5-mm hand piece at 1.5 J (5.2 J/cm^2), 500-μs pulse duration. The CO_2 protocol was not used in this subset because of our team's concern for potential pigment changes.

The average patient age was 53 years (range, 39 to 74 years). Fitzpatrick skin types included types I–IV. Exclusion criteria were patients with lesions suspicious for malignancy, history of hypertrophic scarring or keloid formation, a history of isotretinoin therapy less than 12 months before treatment or pregnancy.

Before treatment, all patients provided informed consent. All patients were placed on 0.05% tretinoin emollient cream (Renova®, Ortho Pharmaceutical Corp., Raritan, NJ) applied to the upper lip only at night 10 days before treatment, and 4.0% hydroquinone (Lustra®, Medicis Pharmaceutical Corp., Phoenix, AZ.) applied to the upper lip twice a day for 10 days before treatment. On the day of treatment, sites were cleansed with Cetaphil (Galderma Laboratories, Fort Worth, TX) and anesthetized with local infiltration of a 50:50 mixture of 1% lidocaine with 1:200,000 epinephrine and 0.5% Marcaine.

Patients were instructed to avoid sun exposure and tanning beds 2 weeks before treatment, and tanning was prohibited during the study period. All patients were prescribed prophylactic valacyclovir (Valtrex®, Glaxo Wellcome, Inc., Research Triangle Park, NC.) 500 mg two times daily, taken 1 day before treatment, and continued for 5 days. Additionally, all patients were placed on dicloxacillin 500 mg twice daily beginning the day of surgery for 7 days.

Postoperative skin care was open occlusive petrolatum based topical care without synthetic dressing. After 24 hours, all patients were instructed to apply acetic acid soaks four times daily followed by application of plain petrolatum. Soaks were discontinued upon resolution of crusting and to decrease inflammation, 0.05% alclometasone dipropionate ointment (Aclovate®, Glaxo Wellcome, Inc.) was applied twice daily. In a diary, patients daily recorded erythema, crusting, pain, itching, swelling, and pigmentary changes.

Serial color, black and white, and ultraviolet (UV) photographs were taken with a 35-mm Nikon® macro system (Canfield Scientific, Fairfield, NJ). A Sony VX1000, digital imaging system with Mirror® 2000 software (Canfield Scientific) was also used. Lighting and magnification were standardized. Film from a single emulsion batch was processed at the same laboratory. Photographs and digital images were recorded preoperatively, immediately postoperatively, and at follow-up time intervals 3, 7, and 14 days, and 1 and 2 months after treatment.

Serial chromometer and moisture measurements were taken at similar intervals by using the Minolta CR 200 chromometer (Ramsey, NJ) and a Scalar moisture checker (Scalar Corp., Vacaville, CA). Areas were assessed with the "LAB" chromometer settings, where the "A" value measures erythema. Three sites were assessed, right mid-cheek (control), and right and left lip on each patient.

Objective photo grading by quartiles of improvement were performed in a blinded manner after completion of the 2-month follow-up visit by a team of cosmetic surgeons and trained research assistants (one female, four male) by using matched but not altered digital images of each treatment site. Graders (some authors and some nonauthors) were blinded to treatment parameters and patient identity.

RESULTS

The patient diary data comparing CO_2 alone versus the variable pulse Er:YAG procedure revealed that the duration of crusting was reduced on average from 7.8 days with the CO_2 treatments to 3.5 days with the VP Er:YAG (Figs. 1 and 2). Postoperative erythema was decreased on the side treated with the variable pulse Er:YAG, but this did not reach statistical significance (Fig. 3). No permanent adverse events such as hyperpigmentation, hypopigmentation, scarring, infections, or contact dermatitis were observed.

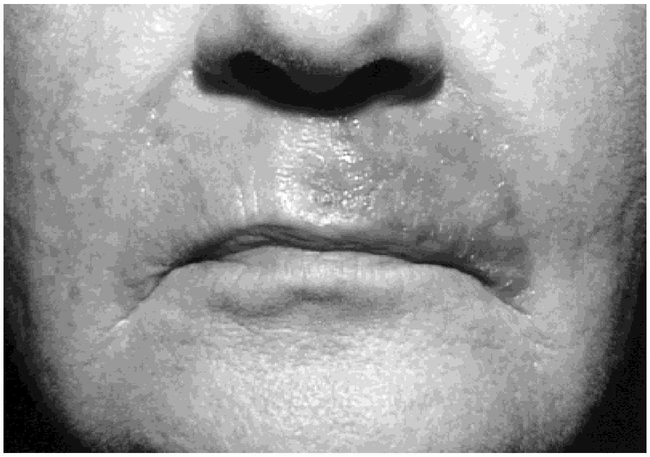

Fig. 1. A 7-day postoperative photo comparing CO_2 laser resurfacing alone (patient left side) versus variable pulse Er:YAG (patient right side).

Blinded objective grading on percentage perioral rhytid improvement showed an overall improvement of 63% in the CO_2 laser treatments and 54% in the variable pulse Er:YAG laser treatments (Figs. 4–6)(3). The breakdown of improvement in the separated Fitzpatrick wrinkle classes are as shown (Fig. 7).

The Asian population subset of this study showed similar improvement between the variable pulse Er:YAG and the standard Er:YAG treatment, with one patient experiencing mild hyperpigmentation, which began around 4 weeks after treatment and cleared by 3 months (Fig. 8).

Ultraviolet reflectance photography was performed in all patients pretreatment, and again at 2 months with marked improvement of photoaging with both laser systems (Fig. 9). Histology of ex vivo biopsy specimens after variable pulse Er:YAG laser treatments, as per the treatment protocol, demonstrated a 90-μm layer of ablati on and 10-μm layer of residual thermal necrosis (Fig. 10).

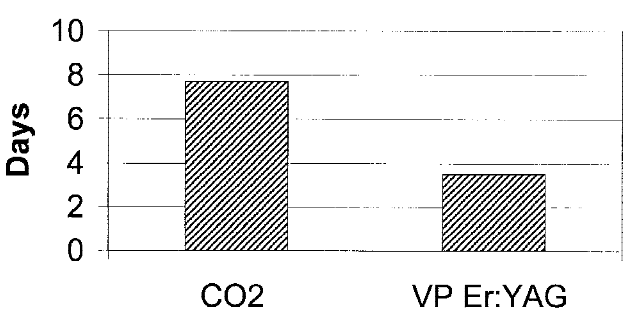

Fig. 2. Time to reepithelialization (days).

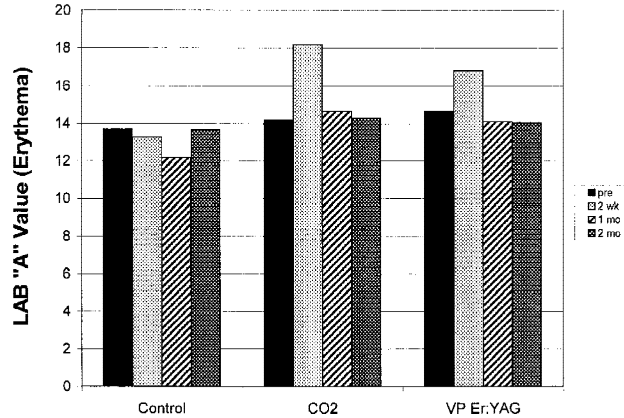

Fig. 3 Chromometer analysis. VP, variable pulse.

DISCUSSION

The availability of numerous resurfacing lasers has provided the cosmetic surgeon with more resurfacing tools than ever before. There exists some confusion regarding the treatment parameters and indications for each laser system for darker skin types. Through the interactions with the researchers, clinicians, and physicist, we are witnessing the technology being designed in accordance with the patient in mind.

Variable pulse Er:YAG lasers such as the one evaluated in the study were produced to provide both a traditional short pulse (ablative) mode and a longer pulsed (thermal) mode, which would in theory, mimic the CO_2 tissue effects.

This study attempted to assess the clinical results of a variable pulse Er:YAG with a "gold standard" CO_2 technique. Most studies have demonstrated comparable results for fine lines and

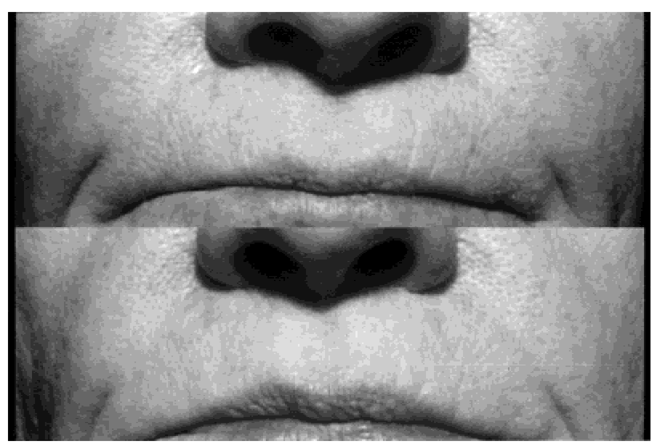

Fig. 4. Pretreatment (**upper**) and 2 month after resurfacing (**lower**) of Fitzpatrick Class II rhytides. Patient left in lower photo is variable pulse Er:YAG and patient right is CO_2.

Fig. 5. Pretreatment (**upper**) and 2 month after resurfacing (**lower**) of Fitzpatrick Class III rhytides. Patient left side in lower photo was treated with variable pulse Er:YAG and patient right side is CO_2.

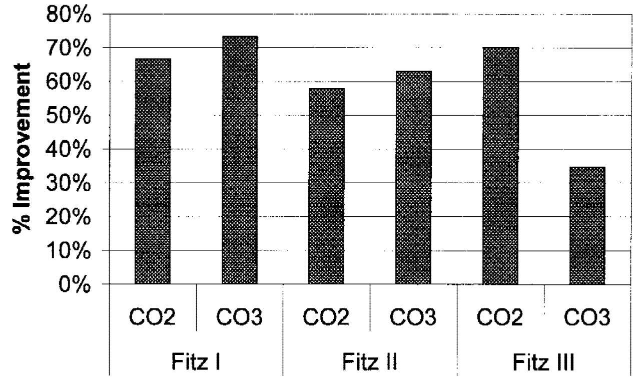

Fig. 7. Percentage improvement in Class I, II, and III wrinkles. Fitz, Fitzpatrick classification.

wrinkles, but relatively poor results for Er:YAG for moderate to severe lines. This study found an increased thermal effect from the variable Er:YAG technique and also improved clinical effects for moderate to severe rhytides while retaining a shorter reepithelialization time. However, the variable Er:YAG was not able to equal the CO_2 clinical results in this study. The study protocol prohibited individual shoulder sculpting to minimize variability in the study. However, individual shoulder sculpting with more passes can enhance the clinical results seen with this laser.

Based on currently available systems, some general observations can be made: CO_2 by using current techniques generally remove up to 220 μm of tissue, leaving a residual zone of irreversible thermal necrosis of 50–100 μm [9,24,25]. An additional zone of reversible thermal injury also remains, which represents the "repairable injury" zone that triggers wound remodeling and in

Fig. 8. Preoperative (**upper**) and 2 months after (**lower**) laser exposure in Asian patient with Fitzpatrick class I rhytides. Patient left side treated with variable pulse Er:YAG and patient right side was treated with 500 μs Er:YAG only. (Note faint hyperpigmentation on variable pulse Er:YAG side.

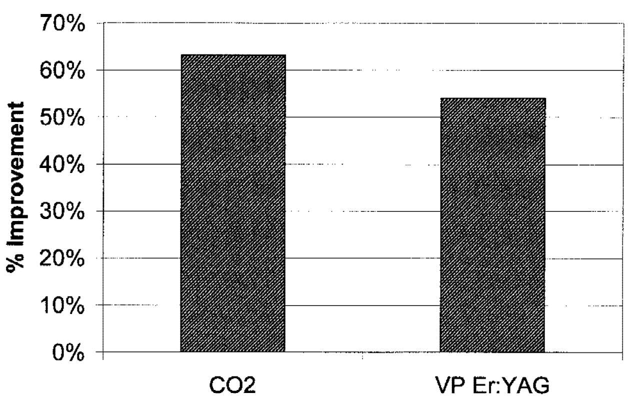

Fig. 6. Blinded physician grading. VP, variable pulse.

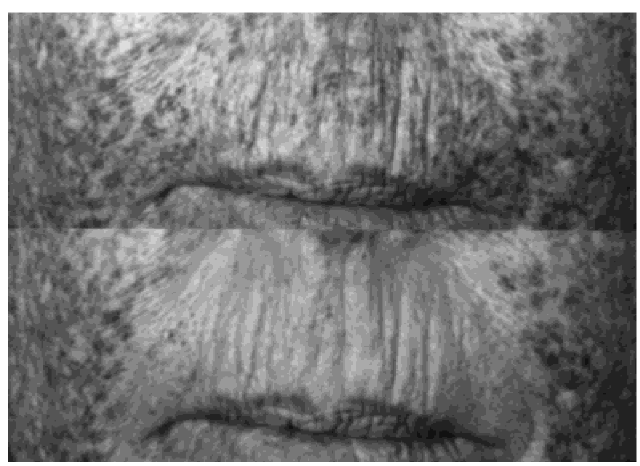

Fig. 9. Preoperative (**upper**) and 2 month after (**lower**) ultraviolet reflectance photography. Patient right side treated with variable pulse Er:YAG and patient left side treated with CO_2.

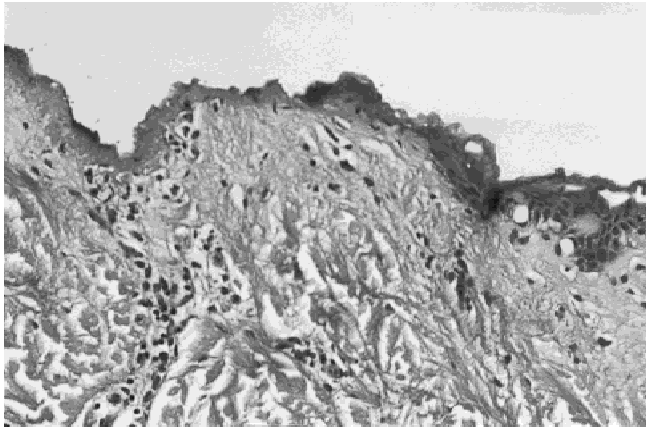

Fig. 10. Ex vivo human face lift skin; hematoxylin and eosin staining; original magnification, 400×. The right side of the image is untreated skin; the left side of the image is immediately after treatment by using study protocol.

which collagen fibril "shrinkage" occurs [3,26,27]. These zones described by Fitzpatrick and others represent the different tissue effects noted between CO_2 and Er:YAG lasers. This residual thermal injury probably creates the desirable tissue tightening and collagen shrinkage, with minimal postoperative bleeding, but also results in the undesired postoperative pain, prolonged erythema, and the potentially troublesome hypopigmentation that may be associated with current CO_2 resurfacing procedures [6,28,29].

In contrast, the traditional short pulsed (250–500 μs) Er:YAG laser creates greater tissue ablation (due to its greater affinity for water than CO_2) leaving behind a much smaller amount of thermal injury. Ablation depth averages only 20 μm per pass (although this depth is increasing with newer, more powerful systems) and, thus, requires more passes but similar operative time than the CO_2 laser systems (Er:YAG treatment time per pass is less than CO_2) [2,15,30]. The zone of irreversible thermal necrosis averages 10–20 μm with a presumably very small zone of reversible thermal injury. Although this study attempted to define the effects of a longer pulsed Er:YAG, much work remains [31]. A 1-year follow-up is needed to determine whether these relative improvements change with time as well as to assess possible delayed hypopigmentation. Long-term UV photographic studies of each of these techniques are presently ongoing for assessment of pigment changes. An equal depth ablation comparison study, to isolate as the only variable, the zone of thermal injury and necrosis, and with ultrastructural studies, would be very useful in learning how to optimize these techniques.

CONCLUSION

Based on the early results from this study, long pulsed Er:YAG laser skin resurfacing generates a greater thermal effect and improved clinical results compared with traditional short pulsed Er:YAG resurfacing. However, these effects do not equal those of standard CO_2 resurfacing. Long-term outcomes as for relative clinical effects and pigmentary changes are yet to be established. The ability to deliver ablative and thermal effects from a single device has potential benefits for both patients and clinicians, serving not as a replacement for the CO_2 but rather helping to bridge the gap between traditional Er:YAG and CO_2 laser skin resurfacing.

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